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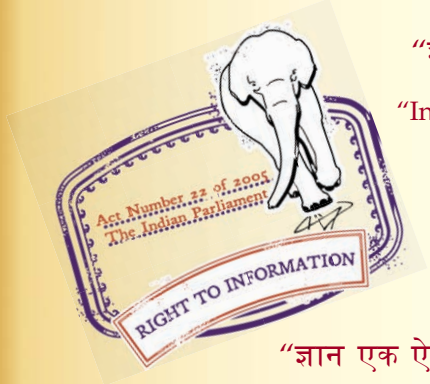
IS 10801 (1984): Recommended procedure for heat treatment of welded fabrications [MTD 12: Welding Applications]

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"Knowledge is such a treasure which cannot be stolen"

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IS : 10801 - 1984
( Reaffirmed 1998 )

# *Indian Standard*

# RECOMMENDED PROCEDURE FOR HEAT TREATMENT OF WELDED FABRICATIONS



UDC 621·785 : 621·772·46 : 621·791



INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5

*June* 1984

# *Indian Standard*

# RECOMMENDED PROCEDURE FOR HEAT TREATMENT OF WELDED FABRICATIONS

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# *Indian Standard*

# RECOMMENDED PROCEDURE FOR HEAT TREATMENT OF WELDED FABRICATIONS

## 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 2 January 1984, after the draft finalized by the Welding General Sectional Committee had been approved by the Structural and Metals Division Council.

**0.2** In the manufacture of welded fabrications in the shop or at site, it may be necessary, for a variety of reasons, to heat the weld regions or the entire fabrication before commencing to weld ( preheating ), or between passes or after the completion of welding ( postheating ), postheating includes any heat treatment after welding including post weld heat treatment.

**0.3** This standard has been prepared mainly to assist fabricators engaged in the manufacture of equipment for oil refineries, petrochemical plants and power stations. However, the standard will also provide general guidance on heat treatment of all industrial welded products.

**0.4** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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## SECTION 1 GENERAL

### 1. SCOPE

**1.1** This standard recommends procedures to ensure that the heat treatment of welded fabrications is carried out accurately in accordance with the requirements of relevant application standards.

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*Rules for rounding off numerical values ( *revised* ).

**1.2** This standard does not provide heat treatment data, such as the preheating and concurrent heating temperatures for various material compositions and their thickness, postheating temperature ranges and time at temperature, and rates of heating and cooling. Such data must be sought from the application relevant standard on pressure pipings, pressure vessels, etc.

**1.3** This standard covers heat treatment of pressure pipework and pressure vessels.

## 2. INTRODUCTION

**2.1** The principal reasons for preheating and concurrent heating is to deaccelerate the cooling rate in the deposited weld metal and the heat-affected zone. This lessens the tendency to form martensite ( in ferritic base metals ), thereby increasing the toughness of the metal in these regions.

**2.2** Postheating can have two beneficial effects, both of which occur simultaneously. One is the tempering of martensite that may have resulted from welding. Such tempering increases the toughness. The other effect is stress relief. The thermal gradients associated with welding result inevitably in residual stresses which may cause premature failure by mechanisms involving delayed fracture, fatigue, or stress corrosion. By the simple expedient or heating the weld zone, the yield strength of the heated material is lowered, and plastic flow can occur to a degree commensurate with the reduction in yield strength. Then when the structure is cooled to room temperature, the level of residual stress has been lowered by the postheat treatment. This decreases the likelihood of premature failure, and also decreases the distortion during any subsequent machining operations.

**2.3** During shop manufacture, welded sub-assemblies or the entire fabrication is sometimes heated in a furnace if size permits. If the fabrication exceeds the size of an available furnace, or if it cannot conveniently be heated in a furnace ( as under site conditions ), the region of the weld only may be heated by one of a variety of methods.

# SECTION 2 HEAT TREATMENT OF PRESSURE PIPE WORK

## 3. PREHEATING FOR CUTTING AND WELDING

**3.1 General** — No thermal cutting, welding or tack welding should be carried out when the temperature of the parent material within 150 mm of the joint or cut is less than 5°C.

**3.2 Preheating for Cutting** — Preheating for thermal cutting should be applied in accordance with the requirements specified in the relevant specification.

**3.3 Preheating for Welding** — Preheating for welding should be applied in accordance with the requirements specified in the relevant specification ( such as Appendix D of IS : 10234-1982* ).

**3.4 Application** — As a minimum requirement, preheating should be applied locally to the area including the weld preparation, and the temperature should be maintained during the deposition of weld metal ( *see* **4** and **5** ).

**3.5 Methods** — Preheating may be applied by any of the following means:

a) Muffle furnaces;

b) Electric resistance heaters;

c) Induction heating, or gas torches; and

d) Burners.

The choice is dependent on local conditions. The procedure used should ensure a satisfactory temperature distribution around and through the joint to be welded and should not interfere with welding operation. To check that the preheating temperature distribution through the pipe is satisfactory, particularly when thick material is involved and/or heating is from the oneside only, it is recommended that temperature measurements are made at the weld joint.

Where preheating is applied manually with gas torches, care should be taken to ensure an even distribution of heat. Excessive local heating of the pipe surface should be avoided.

Preheat of complex welds should take into consideration the combined wall thickness of all members at the weld joint. Increased preheat temperatures may be required.

## 4. CHANGE OF PREHEATING WITH WELDING PROCESS

**4.1** Where the welding process employed for root runs differs from that used for subsequent runs, the preheating ( if any ) applicable to each process should be determined in accordance with relevant data ( such as Appendix D of IS : 10234-1982* ). Any change in preheating temperatures required should be made after completion of the first process but before commencement of the second process.

## 5. CONTINUITY OF WELDING AND PREHEAT

**5.1** Irrespective of the class of steel, root runs should be made without interruption other than for the changing of electrodes or filler materials

*Recommendations for general pipeline welding.

or to allow the welder to re-position himself. Root runs made in the workshop may afterwards be allowed to cool provided that precautions are taken to ensure slow cooling ( for example wrapping in a dry thermal insulating blanket ). Welds made at site should not be allowed to cool until the thickness of weld metal deposited exceeds one-third of the final weld thickness.

**5.2** When welding other than carbon steel up to 0·25°C, it is strongly recommended that arrangements be made to avoid any interruption of welding. Where such an interruption is necessary, either the preheating temperature should be maintained during interruption, or the joint should be wrapped in dry thermal insulating blankets to ensure slow cooling. Before recommencing welding, preheat should again be applied.

## 6. INSULATION OF WELDED JOINTS

**6.1** Wherever required by the application code, on completion of welding, the joint should be wrapped in dry thermal insulating blankets to ensure slow cooling, unless postheat treatment is applied immediately.

## 7. POSTHEATING

**7.1 General** — The condition of the pipes prior to fabrication and the final heat treated condition of the pipework determine the post weld heat treatment that the pipework and welds or welds only should receive and should be in accordance with the relevant Indian Standard. If the purchaser requires all the welds to be heat treated, he should state so in his enquiry and order. Any departure from the requirements given in the following subclauses and the relevant specification ( such as Appendix E of IS : 10234-1982* ) should be agreed between the contracting parties.

**7.2** It is advisable for the purchaser in all cases to inform the manufacturers the use of pipework is to be put to. Where service conditions are conducive to stress corrosion cracking or involve exposure to hydrogen at a pressure of 7 MPa or higher and a temperature of over 400°C and if required by the purchaser, heat treatment should be carried out irrespective of pipe thickness.

**7.3 Butt Joints and Gussetted Bends** — Butt joints should be heat treated after the completion of all welding. The temperature and time at temperature shall be in accordance with the requirement of relevant specification ( *see* Appendix E of IS : 10234-1982* ).

*Recommendations for general pipeline welding.

Where local post weld heat treatment is used the temperature gradient should be such that the length of material on each side of the weld at a temperature exceeding half the heat treatment temperature is at least $2{\cdot}5\sqrt{rt}$ where '$r$' is the bore radius and '$t$' is the pipe thickness at the weld. Thermocouples may be attached to prove that the required temperatures are achieved on the weld and at the gradient positions.

### 7.4 Branch Connections

**7.4.1** *Carbon Steel* ( $\leqslant 0{\cdot}25$ C ) — welds connecting a set-on type branch to a main pipe should post-weld heat-treated in accordance with the relevant specification ( *see* Appendix E of IS : 10234-1982* ):

a) Nominal thickness of the thicker part is over 30 mm, or

b) Distance ( as required by design ) from the toe of a branch weld to the toe of the weld on an adjacent branch or attachment is less than four times the thickness of the main pipe.

**7.4.2** *Carbon* ( $> 0{\cdot}25$ C $\leqslant 0{\cdot}4$ C ) *and Alloy Steels* — Welds in which either the branch pipe or main pipe is of the carbon ( $> 0{\cdot}25$ C $\leqslant 0{\cdot}4$ C ) or alloy steels should be postweld heat-treated in accordance with the temperature and time at temperature required by relevant specification ( such as Appendix E of IS : 10234-1982* ).

**7.4.3** *Postweld Heat Treatment* — Postweld heat treatment should preferably be carried out in a stationary industrial furnace, but where it is necessary to apply a local heat treatment the temperature gradient shall be such that the length of material from each crotch at a temperature exceeding half the heat treatment temperature is at least:

a) $2{\cdot}5\sqrt{r_m t_m}$ along the main pipe where $r_m$ is the bore radius and $t_m$ is the thickness of the main pipe, and

b) $2{\cdot}5\sqrt{r_b t_b}$ along the branch pipe where $r_b$ is the bore radius and $t_b$ is the thickness of the branch pipe ( *see* Fig. 1 ).

**7.5 Plate Flanges and Attachments** — Heat treatment is based on the nominal value of the sum of the individual throat thickness dimensions for each of the welds joining the flange of attachment to the pipe and not the thickness of the flange or attachment.

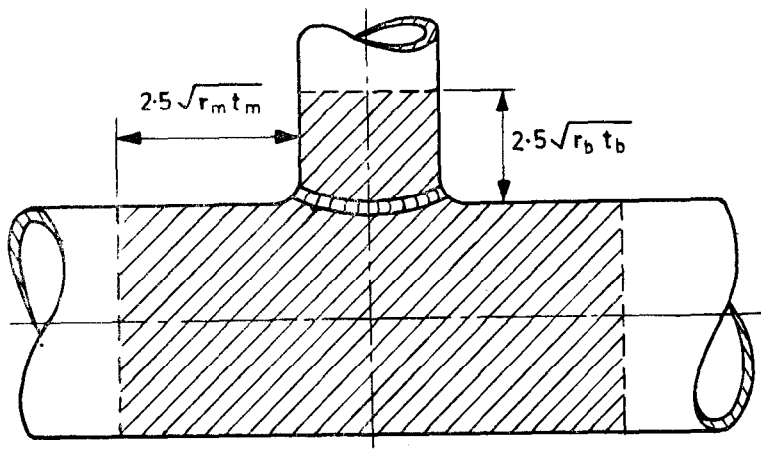
**7.5.1** Carbon steel ( $\leqslant 0{\cdot}25$ C ) — Welds connecting flanges on attachments shall be post weld heat treated in accordance with the

*Recommendations for general pipeline welding.

temperature and time at temperature required by the relevant specifications where:

a) $T$ is over 30 mm,

b) Distance from the toe of a flange weld to the toe of a weld on an adjacent attachment is less than $4T$, where $T$ is the nominal value of the sum of the individual throat thickness dimensions for each of the welds joining the flange or attachment to the pipe.




$r_m$ — bore radius of main pipe
$t_m$ — thickness of main pipe
$r_b$ — bore radius of branch pipe
$t_b$ — thickness of branch pipe

FIG. 1 AREA ( SHADED ) TO BE HEATED FOR THE LOCAL TREATMENT OF BRANCH CONNECTIONS

**7.5.2** *Carbon ( > 0·25 C ⩽ 0·4 C ) and Alloy Steels* — Welds connecting plate flanges or attachments, in which either the pipe or flange ( attachment ) is of the carbon ( > 0·25 C ⩽ 0·4 C ) or alloy steels should be postweld heat treated in accordance with the temperature and time at temperature required by relevant specification ( *see* Appendix E of IS : 10234-1982* ).

**7.5.3** *Postweld Heat Treatment* — Postweld heat treatment should preferably be carried out in a stationary industrial furnace but where it is necessary to locally heat treat plate flanges, the whole of the flange should be heated and the temperature gradient along the pipe should be such that the length of material adjacent to the weld at a temperature exceeding half the heat treatment temperatures is at least $2{\cdot}5\sqrt{rT}$ where

*Recommendations for general pipeline welding.

$r$ is the bore radius and $T$ is the nominal value of the sum of the individual throat thickness dimensions for each of the welds joining the flange or attachment to the pipe.

NOTE — To eliminate heat treatment on site work it is recommended that welded attachments should not be made direct to the pipe. Instead, intermediate plate or plates should be welded to the pipe in the shop, heat treated where necessary, and the attachments welded to the intermediate plates at site.

**7.6 Methods of Heating** — Heat treatment should be carried out by one of the following methods, care being taken to ensure that the minimum stipulated temperature is achieved through the thickness of the pipes:

a) heating in a stationary industrial furnace, or

b) local heating, such as:

i) portable muffle furnace,

ii) induction coils, and

iii) resistance heaters.

Manually operated gas torches should not be used.

Alternative methods of heating which preclude the use of thermocouples and have heating rates in excess of those given in relevant specifications ( *see* **7.7** and **7.7.1** ) may be used provided that the reproducibility of the technique can be demonstrated to the satisfaction of the purchaser or his representative and it can be shown that the method is metallurgically acceptable for the steel involved.

**7.7 Heating Rate** — When a stationary furnace is used, its temperature should not exceed 400°C at the time the pipework is inserted. The temperature specified should be the temperature of the furnace load determined by thermocouples with effective contact with the load.

**7.7.1** The heating rates above 400°C should be appropriate to the alloy composition of the pipework, and as specified in relevant specifications.

**7.8 Cooling After Heat Treatment** — Parts should be allowed to cool down to 400°C at the rates appropriate to the alloy composition of the pipework and as specified in relevant specifications. Below 400°C, the parts may be cooled in still air.

## 8. TEMPERATURE MEASUREMENT

**8.1 General** — Preheating, concurrent heating and postheating temperatures should be checked during the period of their application and all

postweld heat treatment conditions should be recorded. When exothermic packs are used, it may be necessary to undertake hardness surveys to check that the heat treatment has been applied effectively.

### 8.2 Preheating and Interpass Temperature

**8.2.1** Temperature indicating crayons or paints, thermometer thermocouples or pyrometers should be used to check preheating and interpass temperatures.

NOTE — Temperature indicating crayons or paints will not indicate by how much the minimum temperature is exceeded. Some types will not show, once the temperature has been reached, that this temperature is being maintained. In these cases the crayon or paint has to be re-applied if continued temperature observations are to be made.

**8.2.2** When thermocouples are used, they should be located in positions within 40 mm from the outside edge of the fusion faces.

**8.3 Postweld Heat Treatment Temperature** — Thermocouples should be used for recording postweld heat treatment temperatures except where the method of heating precludes their use ( *see* **7.6** ).

They should be dispositioned so as to give a true measure of the joint temperature and where local postweld heat treatment is used they should be located so as to indicate the temperature at significant points of the weld.

### 8.4 Thermocouple Attachment

**8.4.1** Manufactured thermocouples should undergo an initial calibration check, and thereafter should be checked at suitable intervals, which should not exceed 3 months.

**8.4.2** Thermocouple wire used for capacitance discharge direct attachment should have the manufacturer's calibration certificate.

NOTE — The preferred thermocouple is chromel ( Ni 90, Cr 10 )/ alumel ( Ni 98 Al 2 ) with extension cable to the temperature recorder. For high temperature above 1 050°C platinum/platinum-rhodium type is preferred.

**8.4.3** The capacitance discharge welded direct wire attachment type thermocouple should be used for postheating. The gap between the bare conductor wires at point of fusion should not exceed 5 mm and care taken to ensure the mechanical strength of the thermocouple attachment and lead.

**8.4.4** The slotted type attachment should be used for preheat, bearing in mind the following:

a) The conductor wires being fused at the hot junction, this junction to be contained within the slotted nut.

b) The preheat requirements for material being welded should be observed when the slotted nut is being welded to the work piece.

c) There must be a gap of 38 mm minimum between any point of thermocouple attachment and adjacent heaters.

**8.4.5** While using the attachments specified in **8.4.3** and **8.4.4**, special care should be taken to ensure that the thermocouple conductor wires do not touch each other at any point away from the hot junction, and are arranged in such a manner with regard to the disposition of the heaters that the thermocouples are in no way influenced to give false readings.

**8.4.5.1** For postheating, the thermocouple hot junction area should be protected by mineral wool or ceramic fibre or non conducting type insulation from any radiant heat effects from the heaters. Capacitance discharge direct wire attachments need to be protected only by high temperature putty.

**8.4.5.2** The thermocouple to extension cable connection should be well away from any local heat effect, the ambient temperature at this connection and at the extension cable to temperature recorder connection should be the same.

**8.4.6** *Thermocouple Positions* — The thermocouple positions shall be as per the relevant code of application or as agreed between the manufacturer and the purchaser.

**8.4.7** *Thermocouple Extension Cable* — Copper/constantan compensating cable should be used for the extension to the temperature recorder for use with chromel( Ni 90, Cr 10 )/alumel( Ni 98, Ni Al 2 ) alumel thermocouples.

The polarity of all extension cable connections must be correct throughout to ensure that the temperature recorder is reading correctly. With copper constantan compensating cable the copper (+) lead is connected to the thermocouple nickel chromium conductor and the constantan (—) to the nickel aluminium conductor. The compensating cable conductors are easily identified by the metal colour, thermocouple conductors by the nickel aluminium (—) being magnetic, the nickel chromium ( + ) being non-magnetic.

**8.4.8** *Temperature Recorders* — These should be of the potentiometric type. Care must be taken to ensure correct ac voltage is applied to the instrument. Temperature recorders should be calibrated in °C and must be scaled in °C only.

**8.4.8.1** It is equally essential that the correct recorder chart is used that is, it matches with the instrument calibrated range.

**8.4.8.2** Each section of the chart which records a preheating or postheating operation should state or show:

a) Identification of the weld under heat treatment ( drawing and weld No. );

b) Date;

c) For the first two welds of a given geometry a sketch showing the weld geometry, thermocouple positions and reference numbers; for subsequent welds a sketch showing the thermocouple positions and reference numbers only;

d) Chart speed;

e) Site name and job No;

f) Instrument used; and

g) Plant number.

**8.4.8.3** The operator must check the speed of the temperature recorder chart since this will vary between instruments. He should ensure that the correct heating rates and soaking times are maintained.

NOTE — Where thermocouples and temperature recorders are used, it is essential that the particular work piece has a correct welding earth connection and all welding/ heating installations in the vicinity are effectively electrically earthed to ensure the accuracy and safety of the instrument.

**8.4.8.4** Temperature recorders should be calibrated at intervals not exceeding one month. The calibrations should be recorded and evidence to this effect kept with the instrument.

NOTE — It is essential that the engineer carrying out any calibration checks or adjustments to temperature recorders is aware that the thermocouple is chromel ( Ni 90, Cr 10 )/alumel( Ni 98, Al 2 ) type and that the correct checking inputs for this type of thermocouple characteristic are used. The calibration check records must show the instrument indicated temperatures when being checked, that is before any calibration.

**8.4.8.5** The checking instrument itself should be checked in accordance with the manufacturer's recommendations, and in any case not to exceed six monthly intervals.

**8.4.8.6** If the aforementioned check shows that an instrument has been used with an error such that the actual temperatures in preheat or stress relief procedures have been outside the permitted tolerances then full details of the particular welds and the temperature errors must be reported immediately.

**8.4.8.7** Temperature recorders should be serviced by a competent engineer at intervals not exceeding three months when in regular use.

**8.4.8.8** The engineer responsible for the use of the temperature recorders at site must ensure that these calibration checks are carried out correctly.

## 9. INSULATION

**9.1** Mineral wool or ceramic fibre should be used to suit the particular postheating requirement.

**9.2** All gaps between heaters and heaters thermocouples should be lagged.

**9.3** Thermal insulation should extend for a minimum of $2{\cdot}5\sqrt{rt}$ on either side of the heated band to protect against any harmful temperature gradients where $r$ is the internal radius and $t$ is the thickness.

**9.4** All pipes must be blanked off where possible.

# SECTION 3 HEAT TREATMENT OF PRESSURE VESSELS

## 10. PREHEAT REQUIREMENTS

**10.1** To avoid hard zone formation and possibly cracking in the heat affecting zones of welds in ferritic steels, it may be necessary to preheat the parent metal prior to the commencement of all welding, including tack welding. The preheat temperature depends upon the type of joint, the metal thickness, the composition of the steel and the heat input to each run of welding.

**10.2** Recommendations for preheat temperatures given in codes ( such as IS : 2825-1969* ) or its equivalent should be considered as a general guide to good practice. Calculations of preheat temperature to suit particular combinations of heat input, plate composition and thickness for carbon steels can be made by reference to the relevant Indian Standard.

**10.3** The manufacturer should state the proposed preheat temperature for each type of weld including those for all attachments. No welding should be carried out when the temperature of the parent metal within 150 mm of the joint is less than 5°C.

NOTE — Austenitic steels do not require preheat for welding.

**10.4** The preheat requirements for welding should be established between the purchaser and the manufacturer at the time of approval of the welding producers.

*Code of unfired pressure vessels.

**10.5** The temperature should be checked during the period of application. The methods to check temperature are thermocouples, contact pyrometers or temperature indicating crayons.

**10.6** Where preheat is specified welding should continue without interruption. If, however, continuity is affected, preheat should be maintained or the joint should be slowly cooled under an insulation blanket. Before recommencing welding preheat should be applied.

## 11. NORMALIZING

**11.1 Ferritic Steels** — Hot formed parts of vessels require a normalizing or grain refining heat treatment, either before or after welding, unless the process of hot forming was performed within such a temperature range and followed by cooling in such a manner as would provide this treatment for the material concerned.

**11.1.1** Where normalizing is undertaken, the parts should be brought slowly to the normalizing temperature and should be maintained at the temperature long enough for thorough soaking. They should then be uniformly cooled at the appropriate rate. This is generally achieved by cooling freely in still air. Where the geometry of the parts is such that the cooling rate will not be the same throughout, a subsequent stress relieving treatment may be necessary, with particular attention being paid to a slow rate of cooling.

**11.2 Alloy Steels** — In the case of alloy steels, it will be necessary to ensure that the range of cooling rates experienced during normalizing will not result in mechanical properties different from those specified.

## 12. POSTHEATING

**12.1** Postheating in accordance with **14** should be carried out following completion of all welding in the following cases:

a) Ferritic steel vessels designed to operate above 0°C where the wall thickness at any welded connection exceeds that listed in relevant pressure vessel code.

b) Ferritic steel vessels designed to operate below 0°C when postweld heat treatment is necessary in accordance with the requirements of relevant pressure vessel code.

c) Vessels intended for service with media liable to cause stress corrosion cracking in service.

d) Where specified by the purchaser.

**12.2** The recommended treatments apply specifically to the final postweld heat treatment to be carried out on the vessel. In cases where intermediate stress relieving treatments are necessary, consideration should be given to carrying these out at lower temperatures.

**12.3** Where the welded joint connects parts which differ in thickness, the thickness to be used in applying the requirements for postweld heat treatment should be:

a) thicker of the two parts butt welded together;

b) thickness of the shell in connections to flanges, tubeplates or similar connections;

c) thickness of the shell or end plate in nozzle attachment welds.

**12.4** When welded repairs have been made to a vessel which has been postheated the vessel should again be postheated. In special circumstances, and by agreement between the purchaser and the manufacturer, welding may be carried out on lightly loaded and non-pressure parts of the vessels previously subjected to heat treatment, without subsequent reheat treatment, provided suitable tests and controls are instituted to establish that the material will not be adversely affected.

**12.5** For austenitic steels the details of any postweld heat treatment should be agreed between the purchaser and the manufacturer.

## 13. METHODS OF POSTHEATING

**13.1** Wherever possible, the vessel should be postheated as a whole in an enclosed furnace. Where it is impracticable to heat treat the whole vessel in a furnace the methods described in the following paragraphs may be adopted but it should be noted that they may not ensure the same degree of immunity from susceptibility to stress corrosion cracking.

**13.2** The vessel may be postheated in sections in an enclosed furnace, provided the overlap is at least 1 500 mm or $5\sqrt{rt}$ whichever is greater, where $r$ is the internal radius and $t$ is the wall thickness. Where this method is used, the portion outside the furnace should be shielded so that the longitudinal temperature gradient is such that the distance between the peak and half peak temperature is not less than $2{\cdot}5\ \sqrt{rt}$.

**13.3** Circumferential seams in shells may be postheated locally by heating a shielded band around the entire circumference. The width of the heated band should be not less than $5\sqrt{rt}$, the weld being in the centre. Sufficient insulation should be fitted to ensure that the temperature of the weld and its heat affected zone is not less than that specified and that the temperature at the edge of the heated band is not less

than half the peak temperature. In addition, the adjacent portion of the vessel outside the heated zone should be thermally insulated such that the temperature gradient is not harmful. A minimum total insulated band width of $10\sqrt{rt}$ is recommended for the purpose of meeting this requirement. Where branches, manholes or large attachments are close to the circumferential seam, consideration should be given to extend the heated zone thereby reducing thermal gradients across these attachments.

**13.4** Branches or other welded attachments may be locally postheated by heating a shielded circumferential band around the entire vessel. In such cases the requirements of **13.3** should apply with the exception that the width of the circumferential band ( $2{\cdot}5\sqrt{rt}$ minimum ) should be measured from the edge of the welding which connects the nozzle or attachment to the vessel. In cases where these requirements cannot be strictly applied modifications may be agreed between the purchaser and the manufacturer.

**13.5** The vessel may be heated internally, for which purpose it should be fully encased with thermal insulated material. The internal pressure should be kept as low as possible and should not be such as to cause appreciable deformation at the highest metal temperature expected during heat treatment.

**13.6** Vessels of different thicknesses ( not exceeding a ratio of 2 : 1 ) may be postheated in the same furnace charge according to the heat treatment requirements for the thickest vessel in the charge.

**13.7** Where complete postheating of the vessel is to be carried out by internal heating, the vessel should be insulated externally to achieve temperature uniformity in accordance with **14**. Thermocouples will be attached equally spaced to ensure compliance with **14.4**.

## 14. POSTHEATING PROCEDURE

**14.1** Postheating temperature and time at temperature should be as specified in relevant pressure vessel code, taking into consideration the material composition and thickness.

**14.1.1** For vessels made from materials of grades not covered by the pressure vessel code, the temperatrue range should be decided by the manufacturer and the requirements modified as necessary. This should be by agreement between the purchaser and the manufacturer.

**14.2** For furnace heat treatment, the temperature at the time the vessel is placed in it should be as per the applicable pressure vessel code. In the absence of any such stipulation in the code, this temperature should not exceed 400°C.

**14.3 Rate of Heating** — Parts shall be heated at appropriate rate specified in **14.3.1** and **14.3.2.**

**14.3.1** *Other than* $\frac{1}{2}$ *Cr* $\frac{1}{2}$ *Mo* $\frac{1}{4}$ *V and* $2\frac{1}{4}$ *Cr* 1 *Mo Steels* — Irrespective of the method of heating, parts shall be heated to the appropriate temperature at a rate not exceeding the following:

For shell or end plate thickness $t$ up to and including 25 mm: 220° per hour

For shell or end plate thickness $t$ over 25 mm: $\frac{220 \times 25°C}{t}$ per hour, or 55°C per hour which ever is the greater.

**14.3.2** $\frac{1}{2}$ *Cr* $\frac{1}{2}$ *Mo* $\frac{1}{4}$ *V and* $2\frac{1}{4}$ *Cr* 1 *Mo Steels* — Irrespective of the method of heating and of shell or end plate thickness $t$ in mm, parts shall be heated to the appropriate temperature at a rate not exceeding 100° per hour or $\frac{250 \times 25°C}{t}$ per hour whichever is the lower.

**14.4** During the heating period there should not be a greater variation in temperature throughout the portion of the vessel being heat treated than 150°C within any 4 500 mm interval of length. When at the holding temperature, the entire vessel being heat treated shall be within the temperature range specified in the relevant pressure vessel code. The vessel shall be held at this temperature for the periods specified in the relevant pressure vessel code.

**14.5** During the heat treatment the furnace atmosphere should be controlled so at to avoid excessive oxidation of the surface of the vessel. There should be no direct impingement of flame on the vessel.

**14.6 Cooling After Heat Treatment** — Parts shall be allowed to cool down to 400°C at the appropriate rate specified in **14.6.1** or **14.6.2.** Below 400°C the parts may be cooled in still air.

**14.6.1** *Other than* $\frac{1}{2}$ *Cr* $\frac{1}{2}$ *Mo* $\frac{1}{4}$ *V and* $2\frac{1}{4}$ *Cr* 1 *Mo Steels* — Parts shall be allowed to cool at a rate not exceeding the following:

For shell or end plate of thickness up to and including 25 mm; 275°C per hour.

For shell or end plate of thickness $t$ over 25 mm: $275 \times \frac{25°C}{t}$ per hour or 55°C per hour whichever is the greater.

**14.6.2** *½ Cr ½ Mo ¼ V and 2¼ Cr 1 Mo Steels* — Irrespective of shell or end plate thickness, parts shall be allowed to cool at a rate not exceeding 100° per hour.

**14.7** During the cooling period the same criteria of temperature gradient control should apply as during the heating period.

**14.8** The temperature specified should be the actual temperature of any part of the vessel or zone being heat treated, and should be determined by thermocouples in effective contact with the vessel.

**14.9** A sufficient number of temperature readings should be recorded continuously and automatically. Several thermocouples should be applied to ensure that the whole vessel, or zone, being treated is within the range specified and additional pyrometers should be utilized to check that undesirable thermal gradients do not occur.

**14.10** Other temperature and times may be agreed between the purchaser and the manufacturer.

## 15. THERMOCOUPLE ATTACHMENT

**15.1** The thermocouple attachment should be as per the requirements specified in **8.4.1** to **8.4.5.3**.

**15.2** The thermocouple locations shall be in accordance with the relevant code of application or as agreed between the manufacturer and the purchaser.

## 16. THERMOCOUPLE EXTENSION CABLE

**16.1** The thermocouple extension cable should be in accordance with the requirements specified in **8.4.7**.

## 17. TEMPERATURE RECORDERS

**17.1** The temperature recorders should be as per requirements specified in **8.4.8** to **8.4.8.8**.

## 18. SURFACE FINISH

**18.1** Except where otherwise agreed between the purchaser and the manufacturer, the whole of the internal surface of the vessel should be cleaned and should be free from loose scale, grit oil and grease.

**18.2** When special types of finish are to be provided, on the inside or outside surface of the vessel, for example degree of polish, they should be specified by the purchaser at the time of order.

( *Continued from page* 2 )

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## INDIAN STANDARDS

## ON

## WELDING AND CUTTING PROCESSES AND PROCEDURES

IS:

819-1957 Code of practice for resistance spot welding for light assemblies in mild steel

1261-1959 Code of practice for seam welding in mild steel

2811-1964 Recommendations for manual tungsten inert-gas arc welding of stainless steel

2812-1964 Recommendations for manual tungsten inert-gas arc welding of aluminium and aluminium alloys

3023-1965 Recommended practice for building up by metal spraying

4353-1967 Recommendations for sunmerged-arc welding of mild steel and low alloy steels

4 944-1968 Code of procedure for welding at low ambient temperature

6409-1971 Code of practice for oxy-acetylene flame cleaning

8002-1976 Recommended procedure for welding of flexible PVC ( flexible polyvinyl chloride )

8004-1976 Recommended procedure for welding of rigid PVC ( rigid polyvinyl chloride )

8455-1977 Recommended procedure for welding of polyethylene

8987-1978 Recommended practices for air carbon arc gauging and cutting

10186-1982 Recommendations for manual tungsten inert gas arc welding of copper and copper alloys